ANNUAL REPORT

# 1997 CEDAR RIVER SOCKEYE SALMON FRY PRODUCTION EVALUATION

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The success of this project relies on the hard work of a number of dedicated permanent and temporary WDFW personnel. The Hatcheries Program successfully collected and incubated eggs, releasing over 14 million sockeye fry. Eric Volk and Gene Sanborn designed and implemented the otolith-marking program at Landsburg Hatchery. Eric and his staff at the Otolith Lab extracted and analyzed otoliths from the fry sampled at the trap. Scientific Technicians Paul Lorenz, Chuck Ridley and Tim Eichler worked long hours at night operating and maintaining the trap, marking and releasing fry, and enumerating catches. WDFW Wild Salmon Production & Survival Evaluation Unit biologists Mike Ackley and Pete Topping provided valuable logistical support.

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## INTRODUCTION

Adult sockeye salmon returns to the Lake Washington system have declined from peak runs in excess of 600,000 fish as recently as 1988, to under 100,000 fish in subsequent years. In 1991, a broad-based group comprised of representatives of local governments, the Muckleshoot Indian Tribe, state and federal fisheries agencies, academic institutions, and concerned citizens was formed to address this decline. Resource managers developed a program to investigate the cause(s) of the sockeye decline through research and population monitoring in combination with an artificial production program. Information generated by these efforts will be used to devise a restoration plan for Lake Washington sockeye salmon.

Existing management information indicated that marine survival has averaged 13.1%, varying eight-fold (2.6% to 21.4%) with no apparent decline over the data set, which begins with the 1967 brood. In contrast, however, survival during the freshwater phase has declined in recent years. For the 1985 through 1992 broods, freshwater survival (as indicated by the estimated numbers of presmolts produced per spawner) has averaged only 4.8. This rate is only one third of the average production rate of 14.1 presmolts per spawner for the previous 18 broods (1967-1984).

The majority of sockeye production involves two freshwater habitats: the stream, where spawning, egg incubation, fry emergence, and migration to the lake occurs; and the lake, where the juveniles rear for one year before emigrating to the ocean as smolts. Measuring survival rates in both of these habitats requires quantifying the numbers of hatchery and naturally-produced sockeye fry entering Lake Washington as well as estimating the population as spawners and as smolts.

Production at the Landsburg Hatchery began with the 1991 brood. This brood, released in 1992, and all subsequent sockeye incubated at this hatchery, have been identified with thermally-induced otolith-marks (*Volk et al. 1990*). We developed the trapping gear and methodology to estimate sockeye fry production from the Cedar River in 1992.

During the first three years of this evaluation, we determined that survival of hatchery fry from Landsburg to the trap was very low, often less than 10%. In these three seasons, however, flows during most upriver releases were at or near minimum levels. To avoid this high in-river mortality, beginning in the second year (1993), the majority of the hatchery production was transported and released in the lower river just upstream of Highway I-405. In 1995, we evaluated the effect of flow on survival using ten groups released over a range of flows. Results corroborated the earlier estimates, demonstrating that in-river fry survival is largely a function of flow.

Over the first five brood years of this evaluation we have also determined that the survival from egg deposition to fry emigration is a function of the severity of peak flows in the Cedar River during the time that the eggs are incubating in the gravel. Therefore, over the range of spawning population levels we have thus far evaluated, the numbers of naturally produced fry entering Lake Washington are the product of the survival rate and the number of eggs deposited. In 1996 an estimated 230,000 sockeye spawned in the Cedar River, over twice as many as in any of the previous five years.

This report documents the ***1997 Cedar River Sockeye Salmon Fry Production Evaluation***. This trapping project estimated the numbers of 1996 brood Cedar River wild and hatchery-produced fry that entered Lake Washington during 1997.

## GOALS AND OBJECTIVES

The primary goal of this project is to measure total sockeye salmon fry production from the Cedar River. Additional goals include estimating the hatchery and wild composition of the nightly fry emigration throughout the season. Accomplishing these goals enables the following estimates, which are critical for understanding the components of this stock's survival decline and the carrying capacity of Lake Washington for rearing sockeye.

1. **The season total of wild and hatchery fry entering the lake**. Relating the presmolt population the following spring to this estimate measures rearing survival in the lake.

2. **Survival of natural production**. Relating the estimate of wild fry produced to the estimated egg deposition measures the overall average success of natural spawning. Significant variation in this rate among broods, as a function of spawner abundance and flows, will be assessed through correlation analysis. Analysis of wild emigration timing will also provide insight into survival among certain components of natural spawners.

3. **Survival of hatchery fry by release group.** Correlating in-river survival of hatchery fry with release location, timing, flow and total fry density will help explain the interannual variation in survival rates estimated for wild fry. It will also provide guidance for release location decisions.

4. **Incidence of hatchery fry in the population at lake entry**. Comparing this estimate with the incidence of hatchery fish in the population at later life stages (presmolts and adults) will assess relative hatchery and wild survival rates.

## METHODS

We estimated the numbers of sockeye fry migrating from the lower Cedar River by operating a trap throughout the season and calibrating the capture efficiency of this gear. During the first four years of this program, we estimated the hatchery and wild composition of nightly and seasonal migrations based on the proportion of marked otoliths in samples taken each night. Beginning in 1996, we reduced the numbers of fry sampled for otoliths for several reasons; natural fry production was so low that large catches following hatchery releases were obviously hatchery fish, 80% of the hatchery production was released in the lower river just upstream of I-405 and the budget for otolith analysis was limited. In 1997, although natural production was not low, given the budget limitations and the differences in timing between hatchery and wild fry that became even more apparent in 1996, a hatchery release plan was developed that minimized the need to sample catches for otoliths.

### Trapping Gear and Operation

The trap is a low angle inclined-plane screen device (3x2x9 ft.), suspended from a 40x15 ft. steel pontoon barge. This structure resembles the larger traps we use to capture smolts throughout the state (*Seiler et al. 1981*). Each night, we fished the traps at a constant depth, from the surface down 16 in.

As in previous years, we positioned the floating trap at R.M. 0.4, approximately 30 ft. off the left bank. We marked the cables at each anchor winch to ensure that we maintained exactly the same trap position in the channel throughout the season. Lateral positioning is critical, as fry distribution is not uniform or random across the channel. Flows were high early in the season, but as they declined it became apparent that the channel had changed. The thalweg had shifted towards the opposite bank and a gravel bar which extended out from the left bank directed flow and fish away from the trap, particularly at lower flow levels.

We attribute this channel change to the effects of the "ice storm" which produced the winter's peak flows in early January. While the maximum flow at Renton was only 2,830 cfs on January 2, the ice storm downed many trees along the left bank upstream of the trap. This debris slowed the velocity along the bank and vectored flow toward the opposite bank, which is virtually treeless in this reach. Consequently, a gravel bar formed in front of our trap position and a channel was cut near the other bank. Because of the high flows these channel changes were not evident when we began trapping in early-March, when the flow first declined, but because it immediately increased we did not move the trap until April 2, when flows declined again. The trap remained in this new position for the remainder of the season.

We began trap operation on January 23, and fished every other night, through February 10. From this date through May 15, we trapped every night except for part of March 18 and all of the 19$^{th}$. On these nights, high wind and flows up to 2,730 cfs produced heavy debris which precluded trapping. From May 15 through the night of June 8, we fished every other night.

On virtually every date fished, we began trapping before dusk and continued past dawn. To assess the extent of migration during the day, on two dates (March 26 and May 15) we also operated the trap during some daylight hours.

Each hour, on the hour, captured fish were removed from the trap and enumerated. Large fry catches were counted with an electronic fish counter. In 1997 we calibrated this counter again by passing known numbers of fry through it. In these trials the electronic counter counted 96.6% of the actual number of fish passed through it. This rate is only slightly higher than the rate (96.5%) estimated in previous years.

## Trap Calibration

Two assumptions critical for accurate trap calibration involve a known number of fry passing the trap and their capture susceptibility. The first assumption is that all of the marked fry released pass the gear within a certain recovery period. This requirement argues for releasing fish immediately upstream of the trap to minimize their exposure to predation. Marked fry, however, must also be captured at the same rate as unmarked fry. As fry have little ability to avoid the gear in the fast current where we positioned the trap, satisfying this assumption primarily involves achieving the same lateral distribution with marked fry as that of unmarked fry. The further upstream fry are released, the more likely they become distributed as unmarked fry because they are subjected to the same currents.

As in previous years, we estimated capture rate by releasing marked fry at the Logan Street bridge. Fry captured the previous night were marked in a solution of bismarck brown dye (0.014 g/l for 1.5 hours). The bridge is approximately one mile upstream from the trap, and was selected as a compromise between the opposing needs of releasing fish close enough to avoid predation loss and distant enough to insure natural distribution. To assess whether the calibration groups were distributed naturally, we released fry in three groups, from three locations: right bank, left bank, and mid-channel. Release times were separated by an hour or more on many nights to enable analysis of capture rates as a function of release location while using only one mark. Releasing marked fry every other night allows us to assess the proportion of each night's mark group that did not migrate within the release night. In 1997, we released marked fry on 16 nights at the first trap position from February 21 through April 1. After moving the trap to the new position on April 2, we released marked fry on 38 nights from April 3 through May 15.

We also assessed gear efficiency using estimated recoveries of hatchery fry released just upstream of Highway I-405. Estimating efficiency from these releases involves three assumptions: that the reported numbers of fry released are accurate; that all hatchery fry survived to pass the trap on the release night; and that we can accurately estimate the numbers of hatchery fry captured. Fulfilling this last assumption first involves estimating the wild catch on the nights that hatchery fry are released. These estimates were derived by averaging the wild catches from the previous and following nights when hatchery fry were not released.

Recovery rates were correlated with mean nightly discharge to assess the effect of flow on instantaneous capture efficiency.

<u>Hatchery Releases</u>

Over the season, 14,204,000 hatchery-produced fry were released into the Cedar River. Eighty percent of this production (11,307,000) was transported to the lower river, while the balance (2,897,000) was released directly from the hatchery at Landsburg. Fry were released to the lower river above Highway I-405 (Riviera) on twenty nights between January 28 and April 11, and at the Renton Municipal Airport on eight nights between January 24 and March 6. Upper river releases occurred on eight nights, between January 13 and March 3. Group sizes ranged from 20,000 to 649,000 fry (Table 1). Hatchery fry were identified by three otolith codes, representing early, middle, and late releases.

<u>Sampling Fry for Thermal Marks</u>

As otolith-marks are internal, their detection requires killing fish. In previous years, we collected a sample of fry from the catch each night that hatchery-produced fry were released or may have been present in the lower river (post-release nights). In 1997, we collected otolith samples on eight nights, between February 28 and March 7. These collections followed the last two releases from Landsburg Hatchery on February 28 and March 3. To insure that the samples were not biased by the different migration timing of hatchery and wild fry, we retained a constant proportion (usually 10%) of the catch taken each hour over the entire night. Each morning, we gently stirred the retention tank to thoroughly mix the fry, then we collected 155 fry for the sample.

At this time, otolith analysis is incomplete, and therefore is not included in this report. When analysis is available, we will compare resultant estimates to those reported herein.

<u>Fry Estimation</u>

As in previous years, on most nights in 1997 we calculated the sockeye fry migration past the trap by applying an estimate of trap efficiency to the catch. For the nights that we did not trap, and to apportion the migration estimate into hatchery and wild components, we applied the following methodology and assumptions.

1. On the nights that hatchery fish were released, we estimated wild migration by interpolating from the preceding and following nights on which hatchery fish were not released.

2. To estimate wild migration during the periods early and late in the season when we trapped every other night and for the two nights (March 18 and 19) when high

water and debris precluded trapping, we also interpolated from the preceding and following nights.

These estimates relied on the following assumptions:

a. Hatchery releases to the lower river survived to pass the trap at 100% and all the fry in these groups passed the trap on the night of release;
b. The hatchery fry released at Landsburg Hatchery survived to pass the trap at the rates estimated by the flow-survival study that we conducted in 1995 (Figure 1); and
c. The proportion of fry released at Landsburg that passed the trap on the release night was the same function of flow that we estimated in 1995 (Figure 2).

3. The numbers of wild fry migrating before and after the trapping period were estimated by straight line extrapolation of initial and ending migration estimates based on trapping to selected migration starting and ending dates of January 1 and June 15.

4. On four nights (February 13-14, March 3, and March 13), reconciling the catches, lower river hatchery releases, and levels of wild migration indicated from preceding and following nights without hatchery releases, required adjustments to the efficiency rate used. In each case we lowered efficiency, within the measured range, in order for our catch to estimate the entire hatchery release and the level of wild production indicated from interpolation.

5. Based on the limited daylight trapping it was evident that some level of migration was occurring during the daytime. To estimate the proportion of this migration we expanded the daytime catch data to estimate the daylight catch on these dates. Relating these estimates to respective nightly catches estimates the proportion of the migration occurring during the night. We used this rate to compute 24 hour migration estimates for wild fish and the hatchery fry released at Landsburg.

## RESULTS

### Catch

Nightly catches of sockeye fry increased from 795 sockeye on January 23, our first night of trapping, to several peaks of around 20,000 fry when large numbers of hatchery fish were released to the lower river. On June 8, our last night of trapping, we caught only 164 sockeye fry. Over the season, our combined catch of hatchery and wild sockeye fry totaled 690,783 for the 114 nights that we trapped (Table 2).

Efficiency and Flow

Recapture rates of the first 16 calibration tests using bismarck-dyed fry ranged from .68% to 3.88%, and averaged 2.11%. These tests were conducted at the first trap position from February 21 through April 1. Capture rates of the 15 groups of hatchery fry released to the lower river while we were trapping had a nearly identical range, from 0.63% to 3.89%, but a slightly higher average (2.48%). After moving the trap further out into the river to the position we fished after April 2, efficiency increased to an average of 2.62%. Recapture rates at this site were also more consistent ranging from 1.72% to 3.93% over 38 trials. Only two hatchery releases occurred within this strata, one of which was caught at an indicated rate of 8.3%, four times higher than the 2.07% that we estimated with dyed fry on the same night, and over twice as high as the highest value estimated with any of the releases in 1997. As this hatchery release was the smallest of the year (only 20,000 fry), we believe that somehow it was biased. Therefore, we excluded it from our analysis.

On the nights, that we estimated capture rates, flows at Renton ranged from 770 cfs to 2,050 cfs at the first trap position, and from 830 cfs to 1,590 cfs at the second position. Correlation analysis indicated no significant relationship between flow and capture rate. Capture rates at the first position, however, did vary more than at the second position especially at lower flows (Figure 3).

Over all previous five seasons, flow explained most of the variation in capture rates. As explained above, we attribute the lack of correlation between efficiency and flow during the 1997 season to the dramatic changes in the channel at the trap site. This channel shift was caused by the trees along the west bank which dropped during the ice storm on January 1, vectoring the current toward the opposite bank which is treeless.

Instead of using a flow-based efficiency model to estimate our capture rate, each night we used actual calibration values for the nights that we conducted such tests. On the nights that we estimated capture rates with both hatchery releases and dye groups, we used the average of the rates. On the nights that no calibration tests were conducted, we used the overall average recapture rate for each position (Table 3).

Diel Migration

In several previous years, trapping during limited intervals during daylight indicated very few sockeye fry emigrating. Based on these results we concentrated all of our trapping effort on the hours of darkness. In 1997, we trapped during the day for a total of 17.5 hours over just two days and found considerably more fry migrating during the day than we had previously. We believe that flows and associated turbidity explain this discrepancy. In 1997, flows were in excess of 1,000 cfs on all but a few days (Figure 4). In contrast, all of our daylight fishing in the earlier years was conducted during very low flows (around 350 cfs), when the water was clear.

We estimate that on March 26 and May 15, 13.1% and 8.1%, respectively, of the twenty-four hour sockeye fry migration occurred during the daylight (Table 4). The higher rate was observed at flows just over 2,000 cfs, while the lower rate was found at 1,500 cfs. In addition to flows, we expect that diel migration changes over the season as a result of two factors; increasing daylight and spawner distribution. Sockeye that spawn early in the season tend to distribute higher in the system than later spawning fish. Sockeye fry that originate higher in the river probably tend to migrate during the daylight more than fry emerging lower in the river.

Given our limited diel migration timing data, we selected the rate of 10% to approximate the numbers of sockeye fry emigrating during daylight hours.

## Fry Production

We estimated 38.3 million sockeye fry entered Lake Washington from the Cedar River (Table 5, Figure 5). Wild fry production accounts for almost two thirds (24.4 million) of this total and hatchery production the balance, 13.9 million fry. These estimates may change slightly when the results of the otolith analysis become available.

Table 5. Estimated wild and hatchery sockeye fry migrations entering Lake Washington from the Cedar River, 1997.

| Period | Dates | ESTIMATED MIGRATION TO LAKE ENTRY | | | | |
|---|---|---|---|---|---|---|
| | | Wild | Hatchery | | | |
| | | | Landsburg | Riviera | Airport | Total |
| Before trapping | January 1-22 | 392,537 | 651,222 | 0 | 0 | 651,222 |
| During trapping | January 23-June 8 | 23,981,323 | 1,912,161 | 8,122,000 | 3,185,000 | 13,219,161 |
| After trapping | June 9 - 30 | 20,847 | 0 | 0 | 0 | 0 |
| Total | | 24,394,707 | 2,563,383 | 8,122,000 | 3,185,000 | 13,870,383 |

## Wild and Hatchery Migration Timing

Releases of hatchery-produced fry began on January 13 and continued through April 11 (Figure 5). The wild fry migration was under way when we began trapping on January 24, peaked during March and April, and was essentially over when we quit trapping in early-June. The median migration date for hatchery fry occurred on February 20, while the median date for the wild migration occurred on April 7, over six weeks later (Figure 6). This difference results from at least three factors:

1. Proportionally higher egg takes from the early and middle parts of the run than the later segment.
2. Incubating eggs at slightly elevated water temperatures relative to river water.
3. Any eggs deposited after the peak flow event on January 2 experienced higher survival than those from earlier spawners.

Wild timing in 1997 was similar to that observed in 1996 which was later than all of the five preceding broods. Timing of hatchery fry in 1997 was the earliest of the six broods assessed thus far with a median migration date of February 20. Combined migration timing in 1997, however, is just two days earlier than the average of the previous five broods (Table 6).

Table 6. Median migration dates of wild, hatchery, and total (combined) sockeye fry populations, Cedar River.

| Brood Year i | Trap Year i+1 | MEDIAN DATE | | | Difference (days) W-H |
|---|---|---|---|---|---|
| | | Wild | Hatchery | Combined | |
| 1991 | 1992 | 3/18 | 2/28 | 3/12 | 18 |
| 1992 | 1993 | 3/27 | 3/04 | 3/25 | 23 |
| 1993 | 1994 | 3/29 | 3/21 | 3/26 | 8 |
| 1994 | 1995 | 4/05 | 3/17 | 3/29 | 19 |
| 1995 | 1996 | 4/07 | 2/26 | 2/28 | 40 |
| 1996 | 1997 | 4/07 | 2/20 | 3/16 | 46 |
| | **Average** | 3/31 | 3/5 | 3/18 | 21 |
| | **Avg. previous 5 yrs** | 3/29 | 3/8 | 3/18 | 21 |

Egg-to-Migrant Survival of Naturally-Produced Fry

The severity of peak flow during egg incubation explains virtually all of the interannual variation in egg-to-migrant fry survival that we have measured in the Cedar River over five broods (Table 7, Figure 7). The curve in Figure 7 was derived using the estimates from the previous five brood years.

Survival-to-lake entry of fry produced from the potential egg deposition (PED) of natural spawners is estimated at 7.1% (Table 7). This rate represents an overall average value which is the ratio of 24.4 million fry to an estimated PED of 345 million. This PED is based on the following estimates, assumptions, and counts:

1. an estimated natural spawning population of 230,000 adults in 1996;
2. an even sex ratio;
3. an average fecundity of 3,000 eggs per female.

This survival rate is higher than the rate (5.3%) that we estimated for the 1994 brood which experienced an even lower peak flow level of 2,730 cfs. The difference between these two estimates results from a combination of the following factors.

1. **Changes in the streambed and resultant spawner distribution**. During the two extreme high flow events (over 7,000 cfs) in November 1995 and February 1996, the stream bed was altered by channel movements, gravel scour, and gravel recruitment. These processes transported tremendous quantities of gravel to the lower river. In 1996, sockeye made intensive use of these gravels spawning throughout the lower river all the way down to the lake. Gradient in the lower river is less, so gravels are not as easily scoured; it takes a higher flow to cause the same mortality, and at an equivalent flow, survival is higher. Post-emergent fry survival is also higher because exposure to predation is minimal with the short distance to travel.

2. **Spawning flows**. Flows during October and November of 1994 (278 and 452 cfs, respectively) averaged around half of the flows during October and November of 1996 (498 and 1,105 cfs, respectively). Spawning at lower flows places eggs closer to the thalweg, the zone of highest energy where eggs are more susceptible to scour. In contrast, the 1996 brood spawned in higher flows, thereby depositing their eggs over a broader area, including lower energy zones.

3. **Timing difference of the peak flows**. Peak flows for the 1994 brood occurred on December 27 (2,730 cfs), and again on February 19, 1995 (2,690 cfs). Peak flow for the 1996 brood occurred on January 2 (2,830 cfs -- USGS provisional estimate), and again on March 19 (2,730 cfs). Although the peak flows affecting the 1994 brood were slightly lower, occurrence of the second one in February 1995, a month earlier than the second peak in 1997, impacted a higher proportion of that brood's P.E.D.

4. **Flows during fry migration**. We have determined that flow has a strong positive affect on in-river sockeye fry survival in the Cedar River. As flows during fry migration were higher in 1997 than in 1995, survival from emergence to the lake was higher for the 1996 brood.

5. **Underestimating 1996 Cedar River escapement**. As the denominator in the survival ratio (P.E.D.) is determined by the escapement estimate, error or bias in this estimate is reflected in the survival rate. In previous years the majority of sockeye spawned further upstream, therefore, escapements have been estimated based on spawning ground surveys upstream of R.M. 4.2. In 1996, however, substantial numbers of sockeye spawned downstream of this

point. Escapement upstream of R.M. 4.2 was estimated at 124,000 sockeye, based on seven surveys. From R.M. 4.2 to 1.4, 62,000 sockeye were estimated based on four surveys. Three surveys were conducted in the lower 1.4 to 0.0 river miles, estimating 44,000 sockeye (*Egan and Ames, WDFW memo 1997*). Considering that the lower 4.2 R.M. was surveyed half as intensively as the upper, it is wider and flows were much higher later in the season, coinciding with spawner timing in the lower river, it is likely that escapement in the lower river was underestimated. Therefore, the actual egg deposition is higher than the 345 million calculated from the estimate of 230,000 spawners, and survival-to-fry is commensurately lower.

If we attribute all of the difference between these two survival estimates to the underestimate of spawning escapement in 1996, then the actual escapement is calculable. Back-calculating from our 1997 wild fry estimate using the 1994 brood survival rate of 5.3%, estimates a spawning escapement in 1996 of 306,000 adults. We believe this estimate is high, however, due to the first four reasons listed above. A more realistic escapement estimate might be something less than 300,000 but higher than 230,000. At a median value of 270,000 adult sockeye, for example, P.E.D. is estimated at 405 million, and survival to lake entry as fry is 6%.

Table 7. Estimated egg-to-migrant survival of naturally-produced sockeye fry in the Cedar River, brood years 1991-1996.

| Brood Year | Estimated Escapement | Females (@50%) | P.E.D. @3,000x | Fry Production | Survival Rate | Flow (cfs) |
|---|---|---|---|---|---|---|
| 1991 | 77,000 | 38,500 | 115,500,000 | 9,800,000 | 8.48% | 2,060 |
| 1992 | 100,000 | 50,000 | 150,000,000 | 27,100,000 | 18.07% | 1,570 |
| 1993 | 76,000 | 38,000 | 114,000,000 | 18,100,000 | 15.88% | 927 |
| 1994 | 109,000 | 54,500 | 163,500,000 | 8,700,000 | 5.32% | 2,730 |
| 1995 | 22,000 | 11,000 | 33,000,000 | 730,000 | 2.21% | 7,310 |
| 1996 | 230,000 | 115,000 | 345,000,000 | 24,390,000 | 7.07% | 2,830 |

## In-river Survival of Hatchery-Produced Fry

We assumed that the flow survival relationship derived in 1995 estimated in-river survival from release at Landsburg to the trap in 1997. Our only opportunity to assess this assumption will be with the two groups released on February 28 and March 3, as we sampled captured fry for otoliths from February 28 through March 7. Results of the otolith analysis were not available at the time this report was prepared. Given the sustained high flows throughout the season, however, we expect that the in-river survival of migrating fry was very high.

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